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ANNUAL REPORT #1

March 1, 1992 -- February 28, 1993
AFOSR Grant # F49620-92-J-0176-P00001
PI -- William R. Uttal
Studies of the Effect of Image Degradation and Recombination

I: Summary

In the first year of this grant progress was made on two major series of experiments. In the first, we examined the effect of noise, brightness, contrast, and geometrical artifacts on a detection task simulating enhanced night vision devices in a series of 10 experiments. An article has been submitted based on this study. In the second, we explored the effects of noise, Fourier filtering, reduced acuity (by means of blocking) and combinations thereof in a discrimination task. Ten experiments also have been carried out in this series and are now being analyzed and a publication is being prepared.

II: Research Objectives

1. This project offers a program of research on the psychophysics of form. It specifically deals with the perception of degraded and incomplete images. We are interested in the effect of image degradation on the ability of an observer to detect, discriminate, and recognize objects and scenes when the quality of the image has been reduced by systematic, quantified image transformations.

2. We are also interested in the complementary and closely related problem of sensory fusion -- how can multiple aspects or dimensions of the degraded and incomplete images be visually processed so that their subjective appearance is of a higher quality than it would otherwise be, and thus the observer's performance be enhanced from what it would otherwise be. The basic question in this complementary case deals with the ability of the visual system to integrate or combine low quality images of, for example, differing resolution to produce a high quality perception. It is a search for the rules of visual spatial combination and for the relative efficacy of what are distinguishable aspects or attributes of stimuli.

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3. The two questions are, therefore, two aspects of the same problem. On the one hand, what effect does degradation have on the percept? and, on the other, how can the effects of image degradation be overcome by utilizing the power of the visual system to integrate or combine degraded images?

4. We approach this problem from two different directions. First, we are carrying out a program of psychophysical studies that examines the effects of degradation and search out the nature of visual multidimensional combination. The long range goals of the psychophysical experiments are to provide information about the effects on performance of the human observer that go beyond rating or ranking of the subjective quality of an image. Second, we will develop computer models and measures of the effects of image degradation and of the visual combination process. The models so generated are intended to provide the foundation of a theoretical standard observer that can ultimately be used to measure and predict image "quality."

III Status of Research

The first phase of our work has moved along well. Two major series of experiments have been carried out. The first, consisting of ten experiments dealt with a detection task in which the images were degraded by the addition of random visual interference (visual noise), by varying the brightness, by varying the contrast, and by adding structured hexagonal artifacts. The work is described in detail in the accompanying technical report. (This paper has been submitted and is now under revision for likely acceptance.) The applied vehicle used to carry out this task was that of amplified night vision devices. Our work provided the basic psychophysical foundations of vision using these devices. We were not able to uncover any previous work of this kind that dealt directly with night vision systems.

In addition to the basic perceptual data, we discovered a curious learning effect. The size of the geometrical artifacts produced a curious pattern of responses in which the influence of intermediate size hexagons could be overcome by extensive experience but that of smaller hexagons could not. A third category, large hexagons, produced no effect from the outset.

The second major series of experiments is now under analysis and a report is being prepared. This series employed a discrimination task in which small solid objects were used as comparison targets. (In the first series, outlined objects were used). The subject's task was to determine if two sequentially presented objects were the same or different. In this series of experiments we used different combinations of three types of image degradations:

acuity reducing averaging over variable sized blocks; Fourier low pass filtering with variable cutoff frequencies; and random visual interference. The ten experiments conducted indicated that the effect of Fourier filtering and blocking was generally small in all combinations and in all orders unless there was a substantial amount of visual interference present. We are currently conducting analyses to determine the interactions between the three different kinds of degradations.

IV Publications

a. Book:

1. Uttal, W. R., G. Bradshaw, S. Dayanand, R. Lovell, T. Shepherd, R. Kakarala, K. Skifsted, & G. Tupper. The Swimmer: An Integrated Computational Model of a Perceptual-Motor System. Erlbaum, 1992.

b. Published Articles:

1. Lovell, R., Uttal, W. R., Shepherd, T., & Dayanand, S. Texture segmentation of natural images using multiple weak operators and spatial averaging. Pattern Recognition, 1992, 25, 1157-1170.
2. Shepherd, T., Uttal, W. R., Dayanand, S., Lovell, R. A Method for shift, rotation, and scale invariant pattern recognition using the form and arrangement of pattern-specific features. Pattern Recognition, 1992, 25, 343-356.
3. Uttal, W. R. On models and mechanisms. Review of Newell, A. Unified Theories of Cognition. Behavioral and Brain Sciences. 1992, 15, 459-460.

c. In Press Articles:

1. Uttal, W. R. Introduction to Psychophysiology of Visual Masking (Bachmann, T. Author), Commack, New York: Nova Science Publishers.
2. Uttal, W. R. Toward a New Behaviorism. In Masin, S. (Ed.) Conceptual Foundations of Perceptual Theory.
3. Uttal, W. R. Pattern Recognition. In Encyclopedia of Human Behavior. Academic Press.
4. Uttal, W. R., Shepherd, T. Dayanand, S., Lovell, R. An integrated computational model of a perceptual-motor system. Proceeding of the 2nd Annual Conference on the Simulation of Adaptive Systems.

d. Submitted Articles Being Reviewed.

1. Uttal, W. R., Baruch, T., & Allen, L. Psychophysical foundations of amplified night vision in target detection tasks.
2. Dayanand, S., Uttal, W. R., Shepherd, T., Lunsdis, C. A particle system model for combining edge information from multiple segmentation modules.

e. Planned Articles

Effect of Image Degradations on Discrimination

V Participating Staff

William R. Uttal, B. S., Ph.D.	PI
Todd Baruch, B. S.	Research Assistant
Linda Allen, B. S.	Graduate Student
Tom Shepherd, M. S.	Graduate Student
Jaggi Kalki, B. S.	Graduate Student
Robert Cole, Ph.D.	Visiting Scholar

VI Coupling Activities

Presentations

1. May 20, 1992 -- Invited Talk -- Beijing Univ. PRC.
 2. May 22, 1992 -- Invited Talk -- Cheng Feng Science and Technology Group, Beijing, PRC.
 3. July 24, 1992 -- Paper presented at XXist International Congress of Psychology, Brussels, Belgium.
 4. December 6, 1992 -- Paper Presented at 2nd Annual Conference on the Simulation of Adaptive Systems, Honolulu, HI.
 5. December 28, 1992 -- Paper presented at William AFB.
- (1-4) -- A Computational Model of A Perceptual Motor System
(5) -- Psychophysical Foundations of Amplified Night Vision

VII New Developments

There were no new patents. Discoveries are of the kind described above. Application of our work is direct to night vision devices and image quality.

VIII Supplementary Information

Progress was very good this year because of our rapid start. Equipment and some software was available and we were underway quite expeditiously. Twenty separate experiments

were carried out over the course of the year. In the near future we plan to start on the second part of our goal -- to recombine some of the degraded images to see how they might synergistically interact to produce better psychophysical performance than when presented alone. We will do this by mathematically merging them, combining them with sequential display, and by binocular methods. We also have acquired an inexpensive voice recognition system which is in the process of being debugged and installed. This will allow us to work on the third of the proposed response modes --- object recognition.

As far as we can tell from an extensive literature search, there is no work being done on amplified night vision comparable to ours. This is an important application of our work that seems to require further attention.